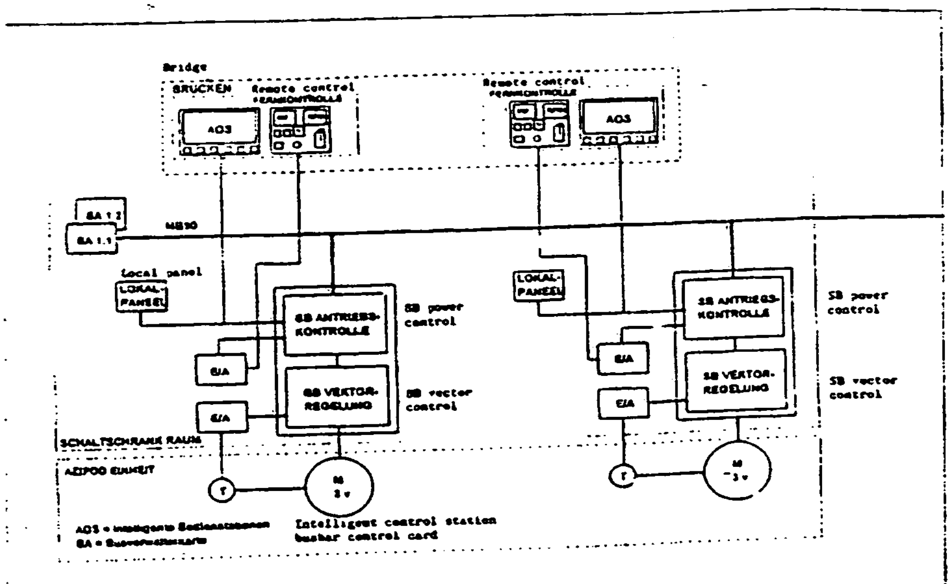
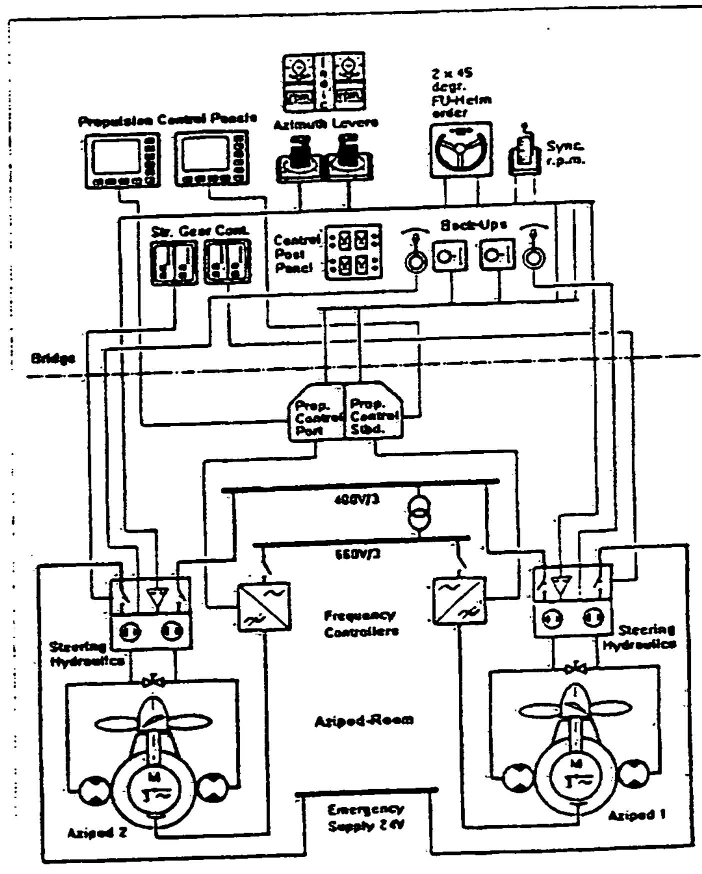
74M1-4 generators of 900kVA. Power is generated at 660V 50Hz and one or both generators feed both azimuth propulsion motors through pulse width modulating inverters, type AGV 700/ABB. The auxiliary network at 400V 50Hz can be connected to the main network or powered by a separate harbour generator set. The Azipod propulsion system is controlled from the bridge. Both diesel generator inverter Azipod combinations have panels of their own integrated to the one man control desk. Corresponding controls are also located locally in the inverter room and there is a limited control station in the Azipod rooms. Communication between the two propulsion controls is through the main controller: if this controller fails a redundant controller will continue the operation.

The inverter is controlled by vector or scalar control. Kvaerner Masa consider that vector is more accurate and faster and it has, therefore, been selected as the main control.

In vector control the excitation and torque is controlled independently throughout the whole speed range. It, therefore, needs a mathematical model including shaft revolution and shaft position information. The data is received from tachometers and each Azipod has two, one in use, one as a spare. In vector control both power and speed control are possible. For icebreaking power control is recommended because it attempts to keep the diesel engine output steady allowing revolutions to vary, instead of vice versa.

In scalar control the motor speed is changed by adjusting the inverter's start frequency, speed and torque of the motor are calculated based on a mathematical model as a function of frequency and current. Generally, the accuracy is not as good as in vector control, especially at low revolutions.




Above: controls for the Azipod propulsion system.
Right: outline of the steering and control system.

## Azipods

The Azipod's asynchronous propulsion motor is located in the submerged pod. The motor is cooled by the water surrounding the pod, roller bearings carry the weight of armature and shaft and all the mechanical elements are designed for the lifetime of the icebreaker. The propeller can rotate in either direction and the Azipod can be turned 360° around its vertical axis. The weight of the pod is carried by a slide bearing and lip seals are used both for the output shaft and the azimuth rotation systems.

The propulsion motor is cooled by the water surrounding the pod but some extra cooling is arranged inside the pod to remove heat from hot spot areas of the motor. Temperature measurements during sea trials showed safety margins of several tens of degrees. A slip ring unit transmits electrical power and data from the non rotating to the rotatable part of the Azipod and overall the unit has been designed and tested especially for ice operations.

The propellers use a new stainless steel. Two main goals were to decrease the weight of the propeller while maintaining strength and to reduce the blade edge thickness to improve hydrodynamic efficiency and to reduce underwater noise. Development of the stainless steel began early in 1993 by Nordberg Lokomo Oy in co-operation with Kvaerner-Masa yards. The new alloy is on the market now under the trade name Arclok. The cavitation and erosion resistance is claimed to be about three times higher than that of the CA-6nm steel. During trials on *Röthelstein* underwater noise measurements were made and visual checks were carried out. These indicate that for naval or research vessel applications where low propeller noise is a requirement, the Azipod propulsion with this propeller material is a realistic choice.

On the icebreaker, steering is by two hydraulic motors to each unit fed by main and auxiliary power packs. The main pump runs off the main electrical network, the emergency pump from batteries. On the bridge there are two azimuthing levers, helmsman's wheel and a separate power lever. The back-up panel includes non follow-up tillers for steering and propulsion power plus alarm and

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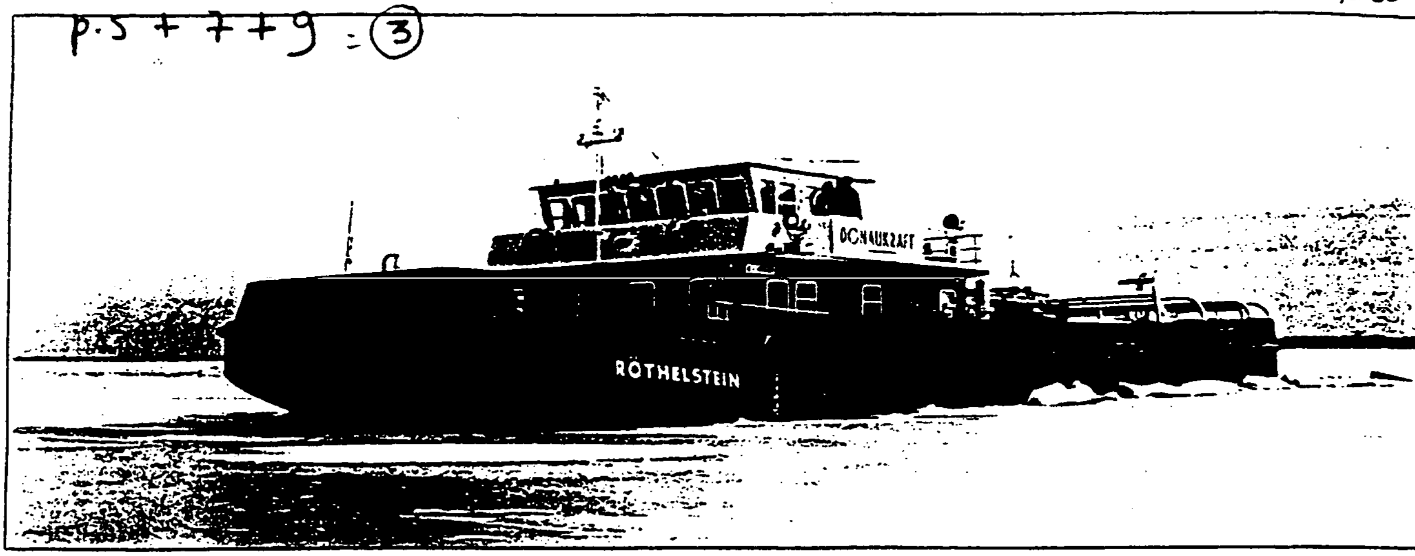



# Austrian river icebreaker with Azipod propulsion

Österreichische Donau Kraftwerke AG recently took delivery of a very shallow draught river icebreaker. The vessel has been named *Röthelstein* and will assist river traffic and break ice in the vicinity of a new power station on the river Danube.

*Röthelstein* was built in Helsinki, Finland, by Kvaerner-Masa Yards, sailed through the new Main-Donau canal and delivered at the Port of Ybbs on the Danube. Following development work at Kvaerner-Masa Yards Arctic Research Centre, the hull design and propulsion system give this small vessel good ice breaking capabilities. Ice trials took place in the Gulf of Bothnia in March of this year and *Röthelstein* proved capable of penetrating 4m thick ice ridges and breaking 0.7m level ice.

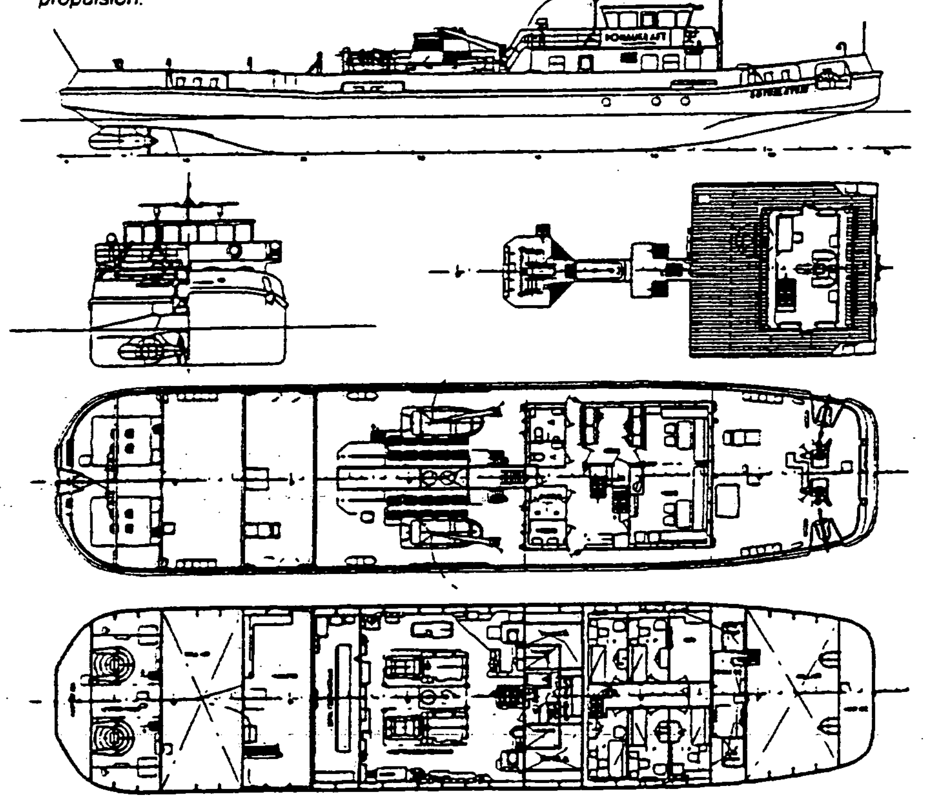
On an overall length of 42.3m and a beam of 10m, the draught is only 2m in normal service and can be reduced to 1.57m. The displacement is around 400 tonnes and a total of 1,120kW in propulsion power is applied using diesel generators feeding two Azipod propeller pods located under the stern. This AC electric transmission was jointly developed by the yard and ABB Industry in Finland. As the illustrations and drawings indicate, this is a low profile craft with a short deckhouse and wheelhouse above. Normal operation is with a crew of three but there is accommodation for up to ten people. The hull itself is in mild steel and the hull form follows current thinking for very shallow draught icebreakers with cylindrical bow, parallel mid body and an underflow stern feeding water to the podded azimuth propulsion units. Deck and hull bottom are longitudinally framed while elsewhere the hull is transversely framed on a 600mm spacing with intermediate frames in the ice contact area. An Inerta 160 epoxy coating system is used, one which is common in icebreaker applications.

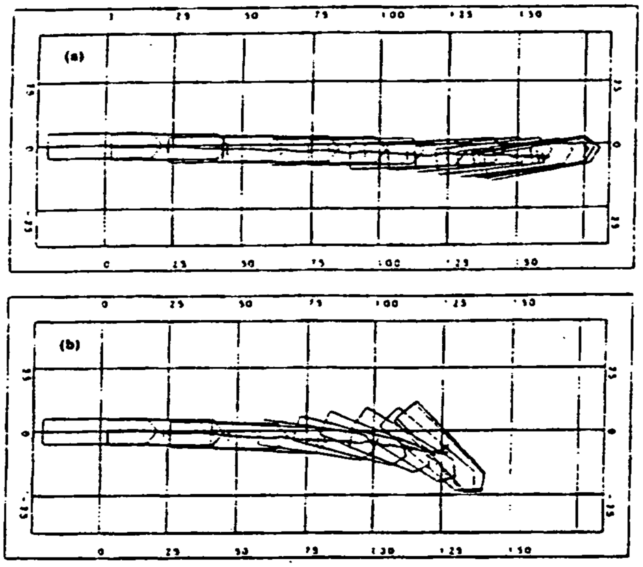
*Röthelstein* is of great interest for its propulsion system, which is the application of the Azipod principle to small powers. The basic design of this podded electric system is proven from earlier units such as those applied to *Seili*, a 1.5MW waterway service vessel and *Uikku* an Arctic tanker with 11.4MW of propulsion power. For this application some further steps have been made, principally the use of a new propeller material, changes to motor cooling and the use of slip rings for power transmission.

**Electric propulsion and controls**

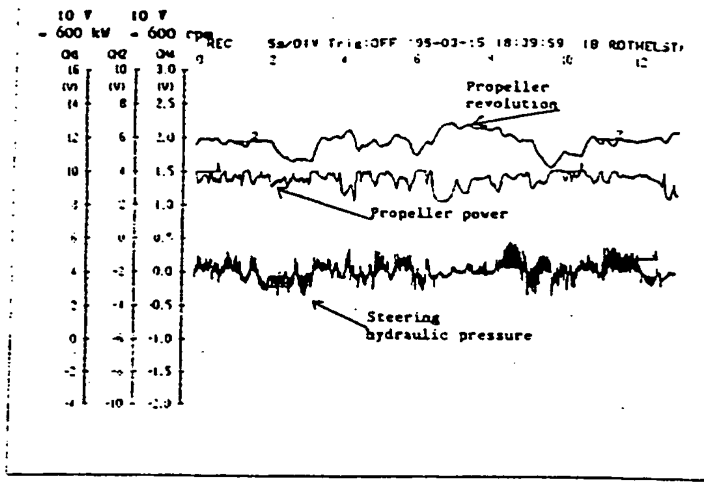
The icebreaker has a diesel electric propulsion system with two diesel generator sets driving two Azipod azimuth electric propulsion units, each of 560kW, through frequency controllers. The main engines are Caterpillar 3508 DITA diesels, each rated at 700kW and these are connected to A van Kaick DSG

*The shallow draught diesel-electric icebreaker* Röthelstein, *with Azipod propulsion.*





Crash stop behaviour (a) by reversing propeller direction and (b) by turning the Azipod units. Vessel position shown every third second. Total time: a – 46 sec. b – 38 sec.




*Propulsion system dynamic behaviour in ice loading condition, maximum propeller power 560kW at 400 rpm.*

monitoring panels. Local operation is also possible. On the main hydraulic system, the azimuthing speed of the units is about 9° per second, or about one-third of that on reserve battery power. A number of operation modes can be selected.

### Transit mode

Both Azipods are synchronised and can be turned ±45° around the vertical axis, this mode is normally used when driving ahead. The Azipods operate with tractor propellers and stopping and reverse is by changing direction of rotation of the propellers. Steering is by the helm and power is controlled by a separate power level.

### Manoeuvring mode

Both Azipods are controlled through azimuthing joysticks which combine power setting and steering. Propeller revolutions and direction of turning can be chosen freely; with the Azipods turned towards each other the propeller power is limited to prevent harmful vibrations. Stopping can be done either by reversing the propellers or turning the units through 180° in either direction. Full thrust is available ahead and astern and this mode is normally used for harbour operations and when breaking ice. For breaking rafted ice, the vessel goes stern first and in this mode the Azipods are set to operate in tractor mode, full power and thrust are available, both propellers can independently break ice and by continuously varying the azimuthing angles between about 10° and 45° no jamming by ice blocks can occur. This is helped by the absence of propeller nozzles and the flushing effects of the propellers are maximised so reducing friction between ice and ships hull. Reverse is normally obtained by changing the propellers' direction of revolution. In emergency steering is by non follow-up tillers and both revolutions and direction of rotation are selectable.

### Open water tests

*Röthelstein* conducted open water sea trials last February in the northern Baltic. The main conclusions were that the icebreaker can turn on the spot, emergency manoeuvres are unrestricted and the vessel can run ahead or astern with either tractor or pusher Azipods. The maximum speed ahead was about 11.6 knots which met the contract requirements. Conversely, very low ship speeds could be achieved easily and in general vibration levels were low. It was found that the crash stop time was about 15% to 20% less by turning the Azipods in azimuth than by changing the directional rotation of the propellers.

### Ice tests

Ice trials were also held in the Gulf of Bothnia. A variety of tests were undertaken, including operation in level ice, penetration of ice ridges, manoeuvring tests and ramming trials. The vessel is designed to operate stern first in difficult ice conditions. The general ice thicknesses were from 55cm to 70cm and 30cm to 42cm. A ridge demolition trial carried out on a ridge about 100m long and varying from 1.5m to 3.6m thick was penetrated in 9mins 30secs. A 180° turn on the spot in an old ice covered channel took 1.5mins to 3.5mins. This small shallow draught icebreaker should, therefore, have ample capabilities for its Danube operations.

At 2 x 500kW this is the smallest Azipod installation to date. The next Azipod delivery will, in fact, be many times the size at 11.4MW in a single unit for the tanker *Lunni*, a sister ship to *Uikku*.

*View under the icebreaking stem showing the Azipod podded propulsion motors.*